YAM PRODUCTION METHODS

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Agricultural Research Service
UNITED STATES DEPARTMENT OF AGRICULTURE

CONTENTS

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YAM PRODUCTION METHODS

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INTRODUCTION

The true yams are vines of the family Dioscoreaceae characterized by starchy underground or aerial tubers. Edible yams are all of the genus *Dioscorea,* which is widely distributed throughout the tropics. A few species of this genus are also found in the temperate zone. Although 60 or more species occasionally serve as food, especially during famine, only about 10 can be considered cultivated. Of these, only four are widespread.

Although edible yams are commonly grown throughout the tropics, they serve as dietary staples only in West Africa and in a few less extensive geographical regions. Other starch-producing plants serve comparable functions and, indeed, compete with yams in the diet as well as in the market. However, each of these crops has its advantages and disadvantages. The tabulation that follows lists these starchy staple plants, geographical locations where important, their relative yields, and state of agricultural technology.

The particular starchy staple used in any region depends upon such characteristics as ease of production, seasonal availability, storage and processing traits, and tastes and customs of the people. Not one of these crops, therefore, can be considered superior in all respects to the others.

Staple crop	Chief geographical areas of importance	Relative yields[1]	State of technology[1]
Rice	Southeast Asia	Medium	Highly advanced.
Cassava	Africa, Brazil, India	Very high	Developing.
Bananas and plantains	Southeast Asia	Medium	Advanced.
Yams	West Africa	High	Primitive.
Sweetpotatoes	New Guinea	Medium to high	Advanced.
Aroids	Pacific Islands	do	Developing.
Potatoes	Andes	High	Do.
Minor roots and tubers[2]	do	Low	Primitive.

[1] Estimates are subject to considerable interpretation (*3*). (Italic numbers in parentheses refer to items listed in Selected References, p. 17.)
[2] Oca, arrowroots, arracacha, and so forth.

PROPERTIES AND CHARACTERISTICS OF YAMS

Yams possess a combination of characteristics that fits them to some, but restricts them from other, geographical areas. They require large quantities of water over a relatively long (6 to 10 months) growing season. However, they do not flourish in poorly drained soils. Most species or varieties will not tolerate more than a few weeks of drought without severe losses in yield. They require a fairly high level of soil fertility and cannot produce on depleted

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soils that might be suitable for cassava. They require supports for climbing. Thus, they are adapted to forest conditions where vines climb to obtain sunlight, but yields are higher when they are grown in full sun with artificial supports.

As a staple food, the following characteristics influence their suitability:

- They are seasonal in production; therefore, they are not available the year around.
- They store well (not as well as potatoes or sweetpotatoes) ; but they lose flavor and quality in storage.
- They can be processed in the home or factory into a variety of nonperishable food products; yet, little has been done to exploit these potentialities.

From a nutritional standpoint, yams compare favorably with potatoes (table 1) and surpass other staple root and tuber crops as sources of protein and amino acids. Tryptophan content is somewhat low. Since yams have not been selected for nutritional value, screening and selection should promptly upgrade protein content and quality.

A final consideration in choice of a staple food plant is that in areas where yams are thus utilized, there is a resistance to supplementing or exchanging them for other staple foods. In West Africa, for example, this crop is a status food. It is served to visitors, and much preferred over less expensive substitutes, such as cassava and tanniers. In the Caribbean, prices are higher for yams than for other locally produced tubers and roots or imported potatoes. Food habits resist changes, and thus a continuing need for yams can be expected.

TABLE 1.—*Total protein and amino acid content per 100 grams food of yams compared with that of other root and tuber crops*[1]

Crop	Protein	Lysine	Methionine	Threonine	Tryptophan
	G.	*Mg.*	*Mg.*	*Mg.*	*Mg.*
Yam	2.4	97	38	74	26
Potato	2.0	96	26	75	33
Sweetpotato	1.3	45	22	50	22
Taro	1.8	70	24	74	26
Cassava[2]	1.6	67	22	43	19

[1] FHO Nutr. Studies No. 24 (*5*).

[2] Cassava data are apparently based on a partially dried sample and should be divided by about 4 to compare them properly with data from other roots and tubers.

PROBLEMS AND OBJECTIVES

The possibility of yams serving larger segments of the population is limited today. They cost more to produce than other root crops, chiefly because so much hand labor is traditionally used. Consumption cannot be expected to increase soon unless better varieties are available, production systems improved, and new processed products developed.

Yams must be recognized as primitive crop plants. Their culture has flourished among peoples of developing countries who have had access only to simple handtools. With some minor exceptions, they have not been grown under conditions of modern agriculture. As yet, they have not been planted densely, heavily fertilized, seeded and harvested by machine, and graded, stored, and processed systematically. To the extent that yams have not been treated by current agricultural methods, they remain unknown, and thus their potentiality compared with other roots and tubers is difficult to assess.

The development of new knowledge of and technology for the yams is needed so that this crop can be utilized to its full capacity. Although other crops may compete with and sometimes displace yams, their general acceptability and particular characteristics will continue to enhance their usefulness.

Two general problems impede a more adequate utilization of yams. First, they exist in a bewildering array of varieties of several different species. They cannot be improved by conventional breeding techniques because most varieties are sterile. A comprehensive introduction and evaluation program is necessary to preserve germ plasm, now endangered in many areas by changes in dietary habits and farming methods, and to evaluate the potential of the

many different varieties. The long-term potentials as well as the short-term uses of germ plasm collections need study.

With a wider knowledge of available varieties, new techniques are needed to produce yams more efficiently. Introduction, testing, selection, and release of varieties might be sufficient for primitive societies where social changes are still absent. As social and economic development occur, better agronomic systems will be necessary.

Modern agricultural practices that can probably be adapted to yams are certified seed programs, preparation of soil, fertilizing and planting by machine, chemical control of weeds and pests, mechanical harvesting, and controlled storage. New and less expensive methods of vine support are needed. Dense plantings producing smaller tubers but greater yields per area are probably desirable. Not all areas of possible study merit equal attention, nor can equal progress be expected. Suggested research priorities and prospects for meaningful progress are listed in table 2.

One particularly troublesome problem needing more attention is that of proper nutrition of yams. Experiments on effects of fertilizers and soil additives have not yielded consistent results. The entire question of nutritional needs of yams will need careful consideration in relationship to the development of more dense plantings, and consequently, higher yields per acre. As yams are crowded into smaller spaces, their nutritional requirements will become more acute and heavier fertilizing may then become beneficial.

TABLE 2.—*Research needs for yams; suggested priorities, and prospects for progress*

Research area	Priority	Prospects for progress
Selection of better varieties	High	Good.
Breeding improved varieties	Low	Very poor.
Development of certified seedstocks	Medium	Medium.
Mechanization of planting	do.	Good.
Improvement of vine support	High	Poor.
Increasing density of planting	Medium	Good.
Utilization of fertilizers for optimum production	High	Medium.
Controlling weeds	Medium	Good.
Controlling diseases and insects	do.	Medium.
Mechanization of harvest	High	Do.
Upgrading handing and storage	do.	Good.
Development of industrial products	Very high	Very good.

The problem of developing better agronomic systems is discussed at length in this publication. However, in contrast to other crops, the yam has not been studied in sufficient detail to permit final judgments about the suitability of some practices. For this reason absolute recommendations cannot be given here when experimental work has not yet been done to justify such recommendations. Successful current practices will be carefully distinguished in the text from probable improvements in practices.

SPECIES OF YAMS AND THEIR POTENTIAL

The principal edible species of yams are easily recognized from either their above- or below-ground characteristics (fig. 1). The species differ also in physiological characteristics, including season of production and time to maturity. Varieties within species are also remarkably varied. Some knowledge of the characteristics of the species is necessary not only for recognizing the difficult species, but also for adjusting agronomic treatments to their particular needs.

Dioscorea alata L. is the best known species of the tropics. Although it is believed to have originated in Burma, cultivated forms spread to India, the Malay Peninsula, South East Asia, Indonesia, the Philippines, and the islands of the Pacific Ocean during Pre-Colombian times. In these areas, the species continued to evolve, and indeed, secondary centers of diversity were thus formed. Early Spanish and Portuguese traders carried the tubers aboard ship for food and for introduction to the colonies. Thus, in a

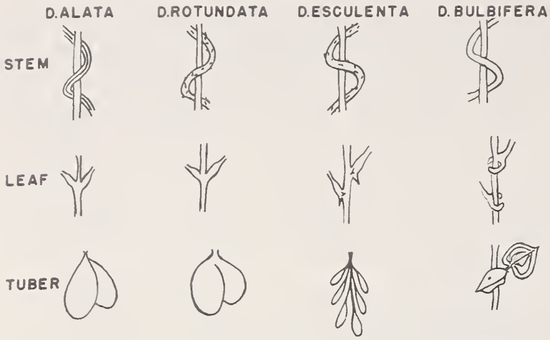

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FIGURE 1.—Pictorial key to the differences among four *Dioscorea* species.

rather haphazard way cultivars of *D. alata* were introduced throughout the tropics, where they are now often considered native. Some varieties also grew wild.

D. alata, sometimes called the greater or the 10-month yam, is easily distinguished from other species by four or occasionally more membranous wings distributed around the stem. These wings may be represented occasionally by insignificant ridges, or modified into spines at the base of the larger stems. At the base of the petioles, the wings widen into prominent auricles, and then continue on the petiole to the leaf itself (fig. 2). Leaves are opposite, and stems twist to the right in climbing. The vegetative parts vary in amount and distribution of anthocyanin. The size and shape of the leaf as well as anthocyanin content often help identify varieties of this species without the necessity of inspecting the tubers. Flowers are sometimes produced during short days in mature plants, but the species is quite sterile and seeds are almost unknown.

Varieties of *D. alata* vary in tuber characteristics. From one to several tubers can be produced, which range in size from ½ to 25 kilograms or more. These tubers may be entire (fig. 3) or branched and may occur in many shapes (such as spherical, cylindrical, spindular, deltoid, and clavate). The bark of the tuber varies in shades of brown. Its flesh may be white, cream, yellow, pinkish, or purple, and the cortex may be a different color. Combinations of characteristics often make varietal identification possible.

On cooking or processing of *D. alata* varieties, other characteristics became apparent. The uncooked flesh of some varieties irritates the human skin (probably because of the presence of calcium oxalate crystals). Phenolic substances of some varieties oxidize rapidly when the yam is cut, or turn gray on cooking. A bitter taste is sometimes found. These characteristics are most apparent in the upper or older parts of the yam, making these parts unacceptable for food.

Cultivars of this species normally require 8 to 10 months of growth before maturity. Generally an early harvest is not feasible because the yam develops most rapidly during the final months before the dry season. During these months, aerial tubers also frequently form. Maturity is generally coincident with short days and the dry season, but even if irrigated, the vines die back. These characteristics restrict the time of availability of this species to a

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FIGURE 2.—Leaf, petiole, and stem of *D. alata*.

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FIGURE 3.—Tubers of a particularly well-shaped variety (Florido) of *D. alata*.

short season. Tubers can be stored in the soil until ready for harvest but are thus left exposed to insects and rodents. On the other hand, the desiccation associated with storage after harvest appears to delay resprouting. The storage life of this species depends on the variety. Although exceptional varieties of yams can be stored up to 6 months, their quality deteriorates.

A yam of almost equal importance to *D. alata* is *Dioscorea rotundata* Poir. (sometimes called *D. cayenensis* Lam.). Whether one or two species are involved can be debated, but conventionally yellow-fleshed, drought intolerant forms are called *D. cayenensis*. These yams originated in West Africa and are distributed chiefly from Nigeria to the Ivory Coast (the so-called yam belt). Some varieties have been distributed to other areas, especially the islands of the Caribbean, but introduction has been haphazard.

D. rotundata, sometimes called the Guinea yam, is also easily characterized. The stem of the species is circular in cross section, smooth or spiny, and twists to the right when climbing. The foliage is glabrous (fig. 4), or sometimes glaucous. Leaves are opposite. Petioles are enlarged at the base but not prominently auricled. The foliage of this species is not as variable in form or in anthocyanin content as that of *D. alata*, and, therefore, varieties often cannot be identified by foliage characteristics. This species is known in both tetraploid and hexaploid forms. When flowering occurs, plants are usually fertile (in contrast to those of other species), crosses can be made, and seedling progeny can be grown. Thus, conventional breeding methods could be applied to improve this species.

The tubers of *D. rotundata* vary remarkably in a way similar to those of *D. alata*. However, the more common forms are compact cylinders and spheres, and the tuber tends less to branch. The bark of the tuber is usually light brown and is thicker and tougher than that of *D. alata*. These characteristics are important in handling the tubers. The flesh is white, cream, or yellow. When cooked, the upper part of the yam may have the same disagreeable colors and bitter flavors as do some varieties of *D. alata*. Better varieties have a rich, characteristic flavor.

The tubers of *D. rotundata* develop more rapidly than those of *D. alata*. If the tubers are carefully removed from the living plant 5 to 6 months after planting, many varieties can be harvested twice during the season. The two harvests are possible because most roots develop from the upper extreme of the tuber. If they are not excessively disturbed, little damage is

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FIGURE 4.—Typical foliage of *D. rotundata*.

done to the plant at the time of the first harvest. Such plants, then, usually develop several small tubers that can be eaten or used as seed for the succeeding year. The second harvest is usually made about 8 months after planting. The foliage of *D. rotundata* dies back at maturity regardless of rainfall. To what extent season of production can be controlled is uncertain.

Those varieties that cannot be made to produce two crops are mostly yellow-fleshed and are usually called *D. cayenensis*. Many exceptions to this generality make rigid classification difficult.

Dioscorea esculenta (Lour.) Burkill is not as well known or as widely distributed as the previous two species. This species probably originated in Southeast Asia, from which it spread to many neighboring islands in Pre-Colombian times. Since then, this yam has been introduced to all parts of the tropics. Still, it is seldom utilized, except on a small scale.

D. esculenta, called at times the lesser or the potato yam, is distinguished by thin, thorny stems that twine to the left. The alternate leaves are nearly circular, rugose, and often pubescent. The petioles are enlarged at the base by three prominent spines. Foliage of all varieties is relatively uniform, making varietal identification difficult. Flowers and seeds are rare.

In contrast to those of other species, the tubers of *D. esculenta* are borne in large numbers at the base of the plant (fig. 5). They are somewhat spindle shaped, weigh from 50 to 350 grams, and may be covered with roots. Superficially, tubers of distinct varieties are usually similar, although differences such as in shape and smoothness of bark can sometimes be noted. Internally, varieties differ in tendency to sting the human skin, in whiteness, sweetness, texture, and amount of fibers. The flavors of most of these yams are excellent; although occasionally some are slightly bitter.

About 9 months are required from planting to maturity. Tubers are harvested when vines die back or 9 to 11 months after planting. If undamaged, the tubers store well.

The potato yam deserves more attention than it has received. This species has most of the characteristics desired in improved varieties including high yields, disease resistance, suitability for mechanization, and good flavor. The starch grains are small and easily digested.

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FIGURE 5.—A group of tubers developed by a single plant of *D. esculenta*.

Several species compete as the fourth species, even though most of them are not widely distributed. *D. opposita* Thunb. is more subtropical than the three species previously discussed, and well known only in China, Taiwan, and Japan. *D. pentaphylla* L. is well known in Indonesia and the islands of the Pacific Ocean. A second species, *D. nummularia* Lam., is grown in much the same area. These yams are borne in convenient clusters, but some varieties need several years to develop large size. In the Caribbean area *D. trifida* L. f. is produced on a small scale. Though one of the better flavored yams, yields are low and, therefore, the species is not of much commercial value.

A final species, *D. bulbifera* L., merits attention because it is so widely distributed throughout the tropics. This species is the only edible one known to have been cultivated in both Africa and Asia before Columbus. Aerial tubers that are produced in quantity and germinate so readily account for the weedy character of the species. The glabrous vines twist to the right; the leaves are alternate. Petioles bear earlike projections that almost completely encircle the stem.

Several characteristics differentiate these varieties. Some bear large, edible underground tubers (fig. 6) but most bear chiefly aerial tubers. The tubers may be spherical or flattened and angular (fig. 7) with yellow flesh. Wild races have acrid tastes or contain poisonous alkaloids, which can be removed by prolonged cooking and washing. The cultivated races are less bitter but cannot compete with other species in palatability.

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FIGURE 6.—Underground tuber of an edible variety of *D. bulbifera*.

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FIGURE 7.—A large aerial tuber of *D. bulbifera*, variety Angled.

VARIETIES

Although varieties are recognized in all parts of the tropics, their names are not standardized and confusion often results. In parts of West Africa, the Caribbean, and the islands of the Pacific, some varieties have been tested. New varieties have not been introduced or tested on a thorough, systematic basis in any of these regions. It is highly probable, therefore, that the varietal situation will rapidly change when such developments occur. Until such a time, some knowledge of accepted local varieties is valuable. Although varietal names are given in the following tabulation, local studies will always be needed to find and describe varieties actually available.

Some criteria for selecting a good variety follow:

- High yield capacity.
- Disease and insect resistances.
- Pleasant appearance and taste.
- Proper shape for harvest and culinary purposes.
- Extended season of availability.
- Capacity to grown without support.
- High nutritional value.

Some better varieties of yams grown in the tropics, by region and species

Region and species	*Varietal names*
Caribbean:	
D. alata	White Lisbon, Florido, Forastero, Oriental.
D. rotundata	Guinea Blanco, Guinea Negro.
D. esculenta	De Papa, de Pana, Chinese.
West Africa:	
D. alata	N'Za Seguela, Bete Bete.
D. rotundata	Akandou, Lokpa, Kangba, Krenglé.
Pacific:	
D. alata	Belep, Noumea.
D. nummularia	Wael.
D. pentaphylla	Wahnaol.

Unfortunately, varietal descriptions have not been made with these criteria in mind, and therefore, no reliable way is known for selecting superior varieties for any geographical region except by soliciting local advice.

ENVIRONMENTAL AND SOIL REQUIREMENTS

The yams mentioned in this publication (except *D. opposita*) are strictly tropical. They require a long, frost-free growing season. A monsoon climate with a short dry season during the shorter days of the year is ideal. Species vary, however, in the details of their seasonal response.

Yams develop best when rainfall or irrigation is frequent so that the soil is almost constantly wet. Nevertheless, they require good drainage for best growth. Standing water prevents normal respiration of the roots and encourages rots and wilts. The root system of yams, which is not extensive, tends to be located close to the surface. Those roots are easily damaged by cultivation or by the soil drying. Yams, therefore, are seldom cultivated except in areas of high, regular natural rainfall where they are cultivated on slopes or where drainage is efficient.

The length of days appears to influence the normal seasonal cycle of many but not all varieties. In the spring when the days lengthen, yams develop vigorous vines. As the season changes and the days become shorter, rate of development increases. Finally, a time is reached, apparently controlled primarily by length of daylight but also influenced by the availability of water, when the vines die back. Early planting does not necessarily lead to early maturity because the seed piece must pass through a period of dormancy. This period appears to be an evolutionary adaptation to alternating dry and wet seasons and, as such, cannot be easily altered. On the other hand, yams that are planted late usually develop tubers and die back at the same time as yams planted earlier. Such plantings do not develop full vine cover, and yields are consequently reduced.

Species and varieties differ in this respect. Some varieties mature tubers and die back earlier than others, while other varieties pass through a longer period of dormancy. These varietal differences serve as one way of prolonging a season limited by natural conditions. The prospects are poor, however, for finding varieties or cultural treatments that make year-round production possible.

The effects of season on yams are well illustrated by the growth of yams brought from the Southern Hemisphere and planted in the Northern Hemisphere. When these yams arrive in the Northern Hemisphere in perhaps, August or September, they have passed through their period of natural dormancy and germinate readily. Later, however, when they are exposed to the short days of the Northern Hemisphere, they do not flourish but may produce new tubers. For some plants the foliage dies back and the tuber enters a new period of dormancy. When these tubers sprout again in the following June, they follow a normal life cycle. If the plant does not become dormant, as daylight lengthens it resumes vigorous and normal growth.

Yams grow vigorously in many soils if their needs for nutrients, water, adequate drainage, and long days are met. In this respect the pH of the soil may be important. If the soil is extremely acid, lime should be added to it. Yams do not thrive in light sandy soils even when carefully fertilized. They are suited best to loamy, well-aerated soils of high-exchange capacity.

On the other hand, yams tolerate clay soils. In Puerto Rico, the best yams are grown in deep, well-drained, tillable clays. They can grow satisfactory in heavy clays, but the tubers may be mishappen because of their inability to expand normally in the soil.

In practice, the drainage requirement is usually met first by choice of soil and planting site, and second, by soil preparation. The most frequent method of planting yams is in mounds or ridges, which raise them above standing water. They can also be planted in benches or holes filled with compost or light soils that carry away excess water. Harvest is simplified, however, if they are planted in ridges. Under conditions of primitive agriculture, ridging or mounding is done by hand with wide hoes or other handtools. However, machines can be used to do the necessary work for good drainage. Subsoil plowing may be necessary at the beginning, then tractor-driven plows and disks could be used to ridge and fertilize. For good drainage and long life, these ridges should be at least 30 cm. high and 60 cm. wide (fig. 8).

Ridging is not always necessary. Yams can be planted without ridging in certain deep and well-drained soils, especially in precipitous regions. Excellent yields have been obtained in such untilled soils in Puerto Rico. Foregoing tillage reduces costs and helps control soil erosion, but more labor is required for harvest.

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FIGURE 8.—Ridges formed by machine for planting yams.

FERTILIZERS

Many investigators have studied the effects of fertilizers on yields of yams in distinct soils and with different cultural practices. Often, the results have been equivocal and contradictory, probably for many reasons. First, in regions where bush-fallow cultivation is practiced, yams are planted as the first crop after fallow, and therefore benefit from the restored

fertility of the land as well as the mineral residues from burning. Second, yams are often planted at such distances that the individual plants do not compete for nutrients. Third, because such a wide array of fertility problems in distinct soils and with distinct varieties has been studied, the results cannot be organized into a coherent pattern. Comprehensive fertility trials of specific varieties in specific soils combined with given spacing and other cultural practices are needed.

Nevertheless, some generalizations can be made. Yams require a high level of nutrients. As yams are crowded into smaller spaces by intensive agricultural methods, more fertilizers will be required and even minor element nutrition will become essential.

Nitrogen appears especially desirable during the first half of the life span of the plant and potassium during the second half. Yams appear to be particularly efficient users of phosphorus, which, consequently, is seldom a limiting factor in production. A fertilizer mixture combining a medium amount of nitrogen, a low amount of phosphorus, and a high amount of potassium would be appropriate. Applications of magnesium have also increased yields in a lateritic soil of Puerto Rico. The best amounts of all these nutrients for particular types of soils should be established by local studies. Soil tests will always be appropriate.

Probably equally important to the production of yams is the method of applying fertilizer. Since newly planted yams contain a reservoir of food from which sustenance is drawn for the first months after planting, the need for fertilizer does not correspond to the time of planting. Yet fertilizer applied later may be easily lost or may damage the plants. A simple alternative is to bury the fertilizer about 12 cm. below the top of the ridge where leaching is minimized. In experiments where a given amount of fertilizer was applied in a single application versus two or three applications, increases in yield resulted when half the fertilizer was applied at planting and half after 3 months. Increases also occurred when one-third of the fertilizer was applied at planting, one-third after 3 months, and the final third after 6 months.

Various investigators have shown that substantial amounts (20 to 50 metric tons/hectare) of organic material added to the soil result in increases in yield. Sometimes green manures are used as a soil amendment. Organic materials improve texture of the soil and increase base-exchange capacity. In addition, they supply nutrients slowly over a long period of time. These effects are more important in soils with low-cation exchange capacity, such as the soils of West Africa. Since organic materials are not always easy to obtain and are bulky and expensive to apply, mineral fertilizers may be substituted when local experiments show them to be feasible. To be effective, ways must be found to distribute fertilizer through several applications, or to use fertilizers that release their nutrients slowly.

General recommendations for fertilizing cannot be given here. Local experiments in yam production should emphasize manuring and fertilizing trials.

PROPAGATION AND PLANTING

Most edible yams rarely flower and almost never produce seeds. They are propagated almost exclusively from small tubers or from pieces of tubers. Details of techniques used vary widely, however.

During the normal dry season, yams pass through a period of dormancy when they will not sprout readily. This period varies from 1 to 6 months, according to both species and variety. At the termination of dormancy, the yams begin to sprout even when they are not maintained in an appropriate environment. Dormancy may be prolonged by storing yams at cool (17° to 20° C.) but not cold temperatures, or it can be cut short by treating the yams for 5 minutes in a 1 percent solution of ethylene chlorohydrin. Some further experimentation is necessary before ethylene chlorohydrin can be recommended and registered for commercial use. Planting also stimulates germination.

The planting piece consists of the so-called headpiece of the tuber or any other part of it

(fig. 9). Headpieces and small tubers contain preformed buds that sprout readily. Other pieces of the tuber do not contain buds, but buds develop rapidly in the cambium of cut pieces. In practice, the different kinds of planting material should be separated so that sprouting at any given site will be somewhat uniform.

Sound, large tubers should be selected for planting. The cut surfaces of the seed yam should be permitted to dry a few days before planting. Since these surfaces are more subject to rotting than other parts of the yam, they are often treated with sifted wood ashes or a fungicide slurry or dust. With healthy yams, this treatment may not be necessary for a curing process can occur under warm, humid conditions (the nature of curing is not yet clear). Seed pieces are either planted a few days after cutting or held until they sprout. If held until sprouted, the pieces have to be handled more carefully and oriented upright in the soil.

The desirable size for seed pieces is controversial. Larger seed pieces sprout more readily, produce more vigorous plants, and yield more per plant than do smaller pieces. Extremely large or giant yams can be produced by using very large (3 to 5 kg.) seed pieces. Such large yams are not as desirable, however, for modern marketing practices. Small seed pieces, although more likely to rot, produce smaller yams but probably yield more on a per weight basis than the larger pieces. Therefore, the size of the seed piece and the planting distances must be adjusted on the basis of the size of the yam desired. Some suggested com-

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FIGURE 9.—A tuber of *D. alata* before (left) and after (right) dividing it into seed pieces.

binations of these factors are given in table 3. Other factors that may affect choice of spacing include soil type (allow more space for heavy soils, and less for sands) and method of staking (if no support given, allow more space). In practice, close spacing will also necessitate extra fertilizing and more careful attention later.

Planting is usually done by digging a hole in the mound or trench with handtools and planting the yam from 5 to 15 cm. below the soil. As the time of planting is often managed to coincide with the beginning of the rainy season, careful manipulation of seed stocks may be needed to make timing exact. When seed stocks sprout, they must be planted immediately even if supplemental irrigation is necessary.

A modern system of yam production should include a program of seed yam production apart from the commercial field. The use of whole seed yams eliminates most risks of rotting and leads to strong, early established plants. Among the methods considered are the production of whole seed yams from very small seed pieces, from aerial tubers, from stem cuttings (fig. 10), and from headpieces after the early harvest of some yams (*D. rotundata*). However, such methods have not progressed to the point of making adequate recommendations here. Facilities for seed production should be carefully managed, especially to rogue out plants with symptoms of virus diseases. Despite these precautions, whole seed yams have not always given good results compared with tuber pieces. The reason for this may be that small whole yams rejected for commercial purposes but retained as seed are often small because of virus infections that reduce subsequent yields.

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FIGURE 10.—Seed yams developed from one-node cuttings of two seed varieties of *D. alata*.

With *D. esculenta*, small whole tubers of 50 to 75 grams make excellent seed. They should be selected from hills of high production and from plants free of virus symptoms whenever possible. In this particular species, but not in others, hill selection has resulted in noteworthy improvement of yields. Such selection, which results in healthier stock, must be continued each year to be effective.

Healthy, mature yam plants are vigorously competitive with weeds and usually shade out most of them during the second half of their life cycle. However, weeds can be a serious problem before plants are well established. Therefore, a preemergence herbicide after planting is appropriate. Both the herbicide atrazine and diuron at rates of 3 kg. and 2 kg. per hectare, respectively, have been used with some success in Trinidad. Atrazine is preferred. Further studies are needed of appropriate methods of weed control.

Herbicides can be injurious to humans, domestic animals, desirable plants, and fish or other wildlife—if they are not handled or applied properly. Herbicides must be used selectively and carefully, following recommended practices for the disposal of surplus herbicide and herbicide containers. In most countries all uses of herbicides must be registered by appropriate agencies before they can be recommended.

TABLE 3.—*Suggested planting distances and sizes of seed pieces, by species*

Species and size of yam desired	Size of planting piece	Distance between rows	Distance between plants
	G.	*Cm.*	*Cm.*
D. alata:			
Small	100	90	40
Medium	150–200	120	80
Large	500–1,000	150	150
D. rotundata:			
Small	215	90	40
Medium	200–250	120	80
Large	1,000–2,000	150	120
D. esculenta:			
Medium	30–50	90	30
Large	60–90	120	40

After the plants sprout, spot control of weeds with contact herbicides is desirable. In less developed areas where herbicides are not generally available, hand-weed control or hoeing will always be necessary.

MAINTENANCE OF THE PLANTING

Since yams are vines, they need objects on which to climb to attain their maximum size and vigor (fig. 11). Without supports a marked reduction in yield occurs because the tips of the vines twist aimlessly and leaves do not mature normally. Nevertheless, in some areas (Barbados), plants of *D. alata* are grown without supports and in West Africa, some varieties of *D. rotundata*. The loss of yield of such plantings is somewhat compensated by the savings in costs of materials and labor for staking. In areas where yams are grown for animal feed or for sale at low prices, this saving is probably justified. Where yams are grown for domestic consumption, however, the increase in yields due to staking probably more than compensates for the increased costs.

The height of the support system appears also to affect yields. On tall supports the plants can develop a vertical cover more extensive than that possible on short supports, which results in an increase in yields. In practice, however, the need for high supports must be balanced against the cost of such supports. Systems of about 1.8 meters are easier to build and maintain than systems of 2.4 to 3 meters. Usually, 1- to 1.2-meter systems are not adequate for good yields. Living supports, such as pigeon peas, maize, tobacco, and bananas compete with the growing yam and reduce yields. Use of living supports may be justified, however, in areas of labor shortages.

Although any kind of durable stick or pole can be used as a support when inexpensive local materials are not available, good supports can be constructed of tall poles. The poles are placed into holes and braced or held upright by cables with horizontal wires strung between

them. Intermediate posts of lighter material must be placed at intervals of 6 to 7.5 meters. Strings attached to the wires, and possibly to the plants, guide the young vines. The system must be strong to support the weight of the vines. In Trinidad one line of poles and wires serves two rows of plants.

In addition to staking, the plants need attention in disease, insect, and weed problems. If fertilizer is placed about the time sprouting occurs, then, precautions must be taken to avoid loss due to leaching by heavy rains. The most obvious technique is to bury the fertilizer near the yam, but this results in damage to feeder roots.

Once well established, yams apparently resist drought, although periods of drought have been shown to reduce yields. Irrigation during excessive drought is desirable and sometimes necessary. Yams adapt very well to high rainfall conditions, but they cannot tolerate very much flooding of their roots and tubers.

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FIGURE 11.—*Dioscorea esculenta* vines climbing bamboo poles.

DISEASES AND PESTS

Yams are relatively resistant to diseases and pests, and are, therefore, frequently grown with very little attention. Nevertheless, serious losses can occur when levels of infestation become high. The principal diseases or pests vary from region to region and from time to time, depending on weather and season. The most common pests and diseases encountered are listed in table 4 with suggested control measures. Local advice should be solicited for specific chemical substances used for control, their rates of application, and pertinent regulations. Cultural practices are often effective. More detailed information on diseases and pests of yams is given by Waitt (*10*) and Coursey (*2*).

HARVEST AND STORAGE

Mature tubers can be stored in the ground until ready for use or until they begin to sprout. This practice leaves them open to attacks by beetles and mammalian pests. Probably, the best time to harvest them is after they mature (see discussion of each species) when the ground is still moist enough to permit digging. Some varieties should be left in the soil a month or more after vines die back, to permit the protective bark to develop at their tips.

Most yams are dug with handtools. They can seldom be pulled directly from the ground without damage. The length of tubers and their tendency to branch require careful harvesting.

A few varieties of yam can be dug by machine. A plow has been adapted for this purpose in Trinidad. Mechanically harvested varieties need to be compact and lie near the surface of the soil.

Immediatetly after digging, the yams should be removed from the sun, cleaned, and sorted. Badly damaged tubers should be disposed of first because they invariably rot. No curing methods have been devised but warm tempera-

TABLE 4.—*Most frequent diseases and pests of yams, and suggested control methods* [1]

Disease or pest	Geographical area where encountered	Symptoms	Suggested control
Virus	Caribbean-Africa	Mosaic, banding, stunting proliferation of buds.	Eradicate diseased plants, do not plant from dwarfed tubers.
Leaf spots	Throughout tropics	Various.	Treat with fungicides, use resistant varieties.
Stem rots	Caribbean	Discoloration of stem, wilting of foliage.	Unknown.
Tuber rots after harvest.	Throughout tropics	Soft, dry, or black rots.	Avoid harvest injuries, cure yams.
Nematodes	do	Root galls, poor health of plants, swelling on surface of tubers.	Avoid infested soils, plant clean materials, rotate crops.
Mites	do	Unthrifty plants, small scars, webs.	Spray with water at high pressures, apply miticides.
Scales and mealy bugs.	Africa, Caribbean	Presence of these pests, weakened plants.	Disinfect tubers, spray vines with insecticide.
Yam beetles	Africa	Lesions on the tubers.	Plant clean materials. Plant as late as possible, rotate crops, dust tuber before planting.

[1] Raw agricultural commodities treated with pesticides (insecticides, herbicides, fungicides, and nematocides) and shipped in interstate commerce in the United States are subject to Federal pesticide regulations. All pesticides used on yams must have Federal registration if yams are to be imported or shipped in interstate commerce.

tures and high humidities aid in the formation of a layer of dead cells that offers protection from fungal infections and loss of water.

Although harvested tubers are frequently stored in piles in shade or in storage bins or houses, the pressure of such storage leads to bruising and deterioration, especially of those on the bottom of the pile. A unique yam barn used in West Africa consists of roofed latticed walls to which yams are tied. Baskets and boxes (fig. 12), if stacked on suitable racks, provide excellent containers.

A major problem in yam storage is weight loss because of respiration and rot. Cool temperatures (20° C.) reduce such losses, but lower temperatures (less than 15° C.), especially if maintained, lead to physiological breakdown that rapidly destroys the entire tuber. The optimum storage temperature is not known for any variety or any effective chemical treatments for reducing storage loss.

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FIGURE 12.—Storage boxes, 1½ bushel, for yams.

POTENTIAL YIELDS

Since yields of a specific crop vary so widely that average measurements have little meaning, figures that represent the highest yields obtained under optimum conditions are perhaps the most useful. Such calculations then serve as guides or goals. Yields at agricultural experiment stations are frequently the most carefully documented, and thus tend to be quoted. Under farm conditions, however, average production is usually much less than that reported at experiment stations. The weight of the planting material may or may not have been substracted from reports of gross yield. Yield figures, therefore, must be interpreted with caution.

A few yield figures obtained from several sources are given in table 5. They indicate that yields tend to be higher in the Caribbean area than in West Africa. The outstanding yields of 67.3 metric tons per hectare of Guinea Blanco (*D. rotundata*) were obtained in a fertilized deep clay soil in the mountains of Puerto Rico (*1*).

Better yield figures accompanied by details of agronomic techniques are urgently needed from all parts of the tropics to assess more adequately the yield potentials of yams.

TABLE 5.—*Yield of yams obtained at selected experiment stations in the tropics, by species and variety*

Location, species, and variety	Yield	
	Per acre	Per hectare
	Tons	*Metric tons*
Puerto Rico:		
D. alata:		
Florido	11.7	29.4
White Lisbon	15.2	38.2
Gordito	24.0	60.4
D. rotundata:		
Guinea Blanco	26.8	67.3
D. esculenta:		
Pana	14.8	36.9
Trinidad:		
D. alata:		
White Lisbon	16.5	41.4
D. esculenta:		
Pana	18.0	45.2
Barbados:		
D. alata:		
Varietal name unknown	[1] 7.0	[1] 27.8
Ghana:		
D. rotundata:		
Dzogboli	7.9	19.8
Nigeria:		
D. esculenta:		
Pana	8.6	21.5

[1] Without vine support.

FUTURE PROSPECTS

Yams are traditional foods that will probably continue to be desired by millions of people. Unless methods are developed for their commercial, mechanized production, they may eventually be supplanted by competing starch-producing crops and their processed products. In Puerto Rico, for example, imported potatoes cost less than half as much as domestically produced yams. Yams are purchased chiefly because they are better known and frequently preferred over potatoes or other starchy roots. Mechanization implies changes in socioeconomic conditions as well as in agricultural practices.

The first obstacle to mechanizing production is the seed piece. A more uniform piece that can be easily planted by machine is desirable. Such a seed piece could be produced potentially in special nurseries apart from the commercial fields. Uniform seed could easily be planted with existing or easily constructed machinery. Other agronomic practices, such as preparation of soil and fertilizing, should not constitute problems in mechanization.

Furnishing appropriate support for the vines is probably the most costly operation. Although machinery is available for staking and string-

ing poles, these systems are probably not heavy enough to support the yam vines. New methods appear unlikely, and staking costs may thus limit the future of yam production. The economics of a stakeless culture or of living support systems merits more extensive study.

Mechanical harvest of yams should not be a problem provided that appropriate varieties are chosen. The range of varietal differences is sufficiently great to make extensive collecting, testing, and selecting worthwhile.

Improving the yam by breeding does not appear to have much promise. Commercial varieties seldom flower and are often polyploid. Improvement by rogueing a variety to type and eliminating virus-infested plants would be of value in many instances.

Finally, finding further uses for the crop, especially in production of animal feeds or in flours and flour products, may yet stimulate the use of this important crop in the modern world of agriculture.

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